

## FUTURE DIRECTIONS FOR NICMOS ARRAYS

by

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## ABSTRACT

The NICMOS project for HST requires focal plane arrays of 256x256 pixels for both its cameras and its spectrometers. The new arrays, developed by the Rockwell Corporation for NICMOS, have 40 $\mu$ m pixels of HgCdTe bump bonded to a switched MOSFET readout. Expected read noise and dark current for the arrays at 60 K are 30 e and 1 e/sec. respectively. The basis for these numbers is previous experience with 128x128 arrays.

## 1 NICMOS and its Environment

NICMOS (Near Infrared Camera and Multi-Object Spectrometer) is a second generation infrared instrument for the Hubble Space Telescope (HST). It contains both cameras and spectrometers for imaging in the 1-2.5 $\mu$ m range and spectroscopy in the

1-3 $\mu$ m region. There are three cameras with differing spatial resolutions, a warm 1-2 $\mu$ m spectrometer, and two cold spectrometers for the 2-2.5, and 2.5-3 $\mu$ m regions. The NICMOS camera and spectrometer specifications are given in tables 1 and 2.

## NICMOS SPECTROMETER SPECIFICATIONS

PARAMETER	MULTI-OBJECT SPECTROMETER	LWS I	LWS II
Wavelength Coverage	1.0-2.0 $\mu$ m	2.0-2.5 $\mu$ m	2.5-3.0 $\mu$ m
Spectral Resolution	100, 1000, 10,000	5000	1000

Table 1.

# NICMOS CAMERA OPTICAL SPECIFICATIONS

PARAMETER	CAMERA I	CAMERA II	CAMERA III	LWS CAMERA
$\lambda/2d$ wave-length	1.0 $\mu\text{m}$	1.75 $\mu\text{m}$	-	-
Pixel size in arc seconds	0.043	0.075	0.2	0.2
Plate scale in arc sec per mm	1.075	1.875	5.0	5.0
Magnification	3.33	1.91	0.716	.716
f/number	79.9	45.8	17.2	17.2
Total field in arc seconds	11	19.2	51.2	-

Table 2..

All of the detectors are HgCdTe arrays with a 2.5  $\mu\text{m}$  cutoff except for the 2.5-3.0  $\mu\text{m}$  spectrometer array which has a 3.0  $\mu\text{m}$  cutoff. The focal plane for each camera and spectrometer has 256x256 pixels which are currently a mosaic of four 128x128 60  $\mu\text{m}$  pixel arrays. The new arrays are full 256x256 arrays with 40  $\mu\text{m}$  pixels. These new arrays reduce the complexity and cost of the instrument and are expected to improve upon the performance of the 128x128 arrays described in this volume by Rieke et al. and Vural et al.. This presentation will discuss only the improvements in the new arrays. Please refer to the previous articles for the details of the present 128x128 arrays.

Figure 1. shows the expected thermal environment encountered

by an infrared instrument on HST. Two emission mechanisms dominate the spectrum. At short wavelengths the scattered Zodiacal light contributes most of the power but at longer wavelengths the emission from the warm HST optical system overwhelms all other emissions. Near the minimum at 1.7  $\mu\text{m}$  the background flux is on the order of 10 (photons/s)/ $\mu\text{m}$ . For spectroscopy and small bandwidth observations the background induced current is substantially below 1 e/sec, therefore, low dark current is an important factor in detector selection.

Note that Fig. 1 is for a 0.2" pixel which is the largest angular resolution for a NICMOS camera. The smallest angular resolution is on the order of 0.04".

TYPICAL HST BACKGROUND FLUX

*HST BACKGROUND VS WAVELENGTH*

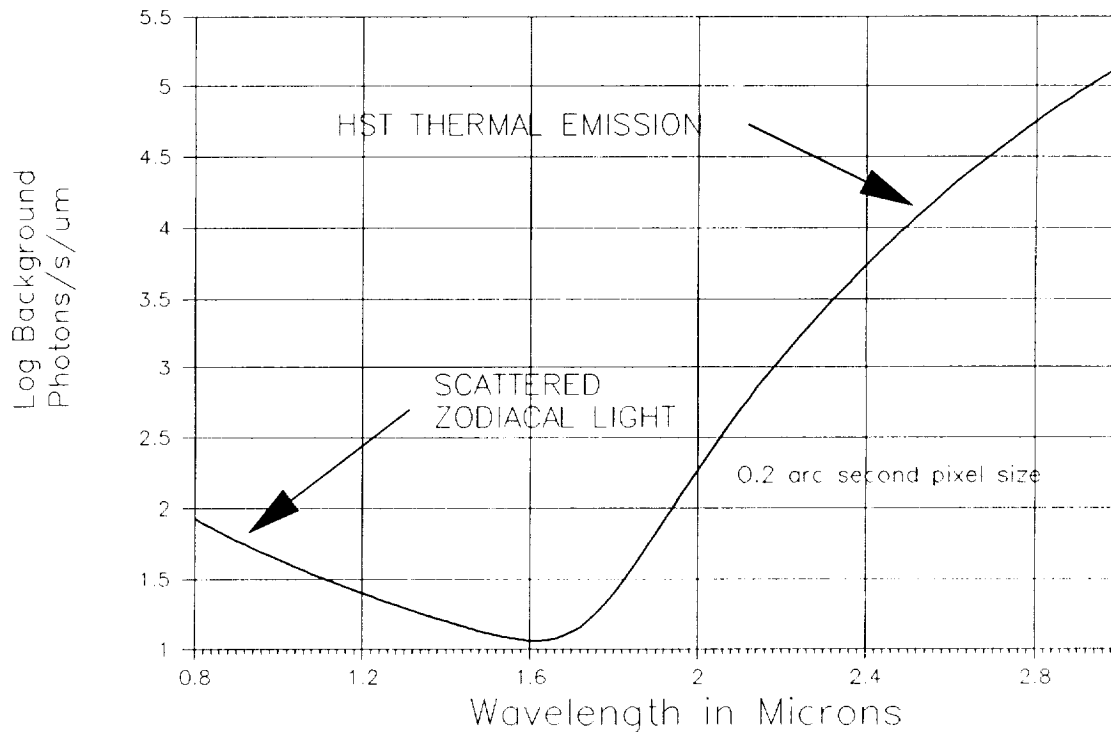


Fig 1.

The three NICMOS cameras and three spectrometers require a total of six independent focal plane arrays. Ease of readout and reduction of associated electronics is therefore an important factor in the array design. At the same time elimination of single point failures in any of the NICMOS instruments is also an important factor. For this reason the NICMOS program is developing two multiplexer designs. The first divides the multiplexer into 4 electrically independent 128x128 quadrants on the same multiplexer chip. The second design reads out the entire 256x256 detector array with a single 256x256 multiplexer. A single readout

reduces the associated electronics for each focal plane and the quadrant design has a high degree of redundancy. A decision between the two designs will be made after reliability information is gathered on both designs. Another factor in the decision is the readout time for each array. For a given speed A/D converter the single output array requires 4 times as long to readout. This is an important factor for the observation of bright solar system objects. Except for the division into quadrants or single readout the features of the new arrays are similar therefore in the remainder of this presentation

they will be described without reference to type except when required.

## 2 NEW MULTIPLEXER FEATURES

Several new features are incorporated into the 256x256 multiplexer design which improve both the signal-to-noise characteristics and the ease of operation. At the same time we have not radically altered the previous design so as to reduce the development risk in the time constrained NICMOS program.

### 2.1 Electronic and Processing Changes

The new multiplexer process is a P channel - N well process which is expected to produce a lower noise system than the previous P channel - P well process. Both the detector and multiplexer substrates are now at ground and the gain in the switched MOSFET system is now 1 instead of 1/2 in the original system. Since the dominant noise is not in the amplifier system, the gain change is expected to produce a corresponding gain in signal-to-noise. All of the multiplexer test points are now buffered to protect the multiplexer during testing.

### 2.2 Logic Circuit Changes

In order to facilitate the readout, the shift registers which access each row and column address of a pixel can be reset to zero. Each shift register can also be clocked independently to quickly access a particular pixel. Although during readout the clocking is significantly slower, the shift registers can be run accurately at speeds up to 10 MHz. If only a small portion of the array has useful data, as in target acquisition, the beginning portion can be addressed quickly via independent row and column clocking. The relevant portion is then read out at the appropriate rate and the shift registers reset to zero to restart the process. Figure 2 shows the basic logic for a single pixel in the multiplexer.

As an additional noise reduction procedure the shift registers are now clocked on both the rising and falling edges. This procedure eliminates the possibility of a transition induced glitch on the signal during the time of measurement.

# MULTIPLEXER LOGIC

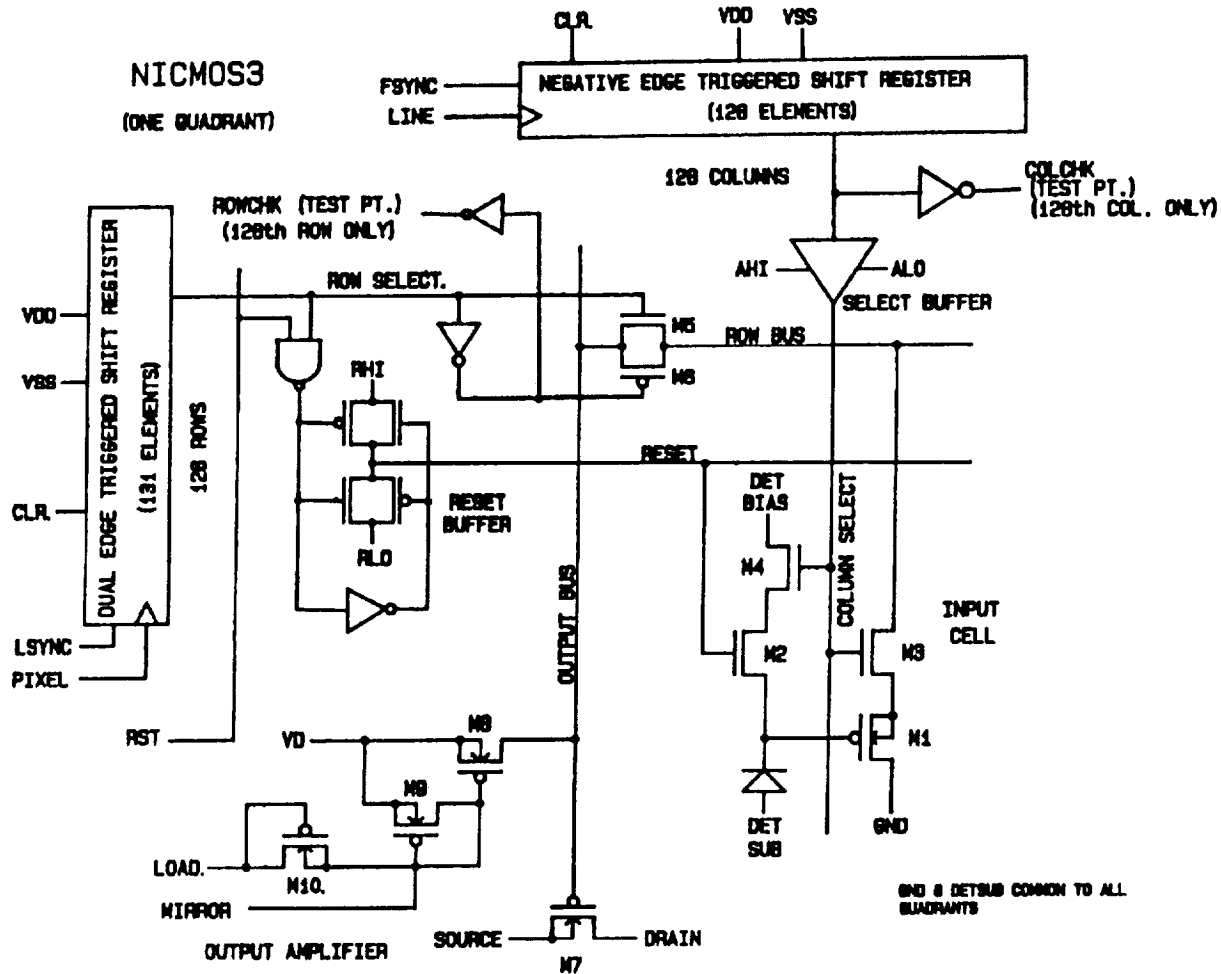


Figure 2

## 2.3 Geometry Changes

The new multiplexer design contains two major geometry changes. In the first change the pixel cell size is now 40  $\mu\text{m}$  rather than 60. The net size of the bump bonded area is then approximately 1 cm. This size is small enough to ensure that the bump bonds remain secure during cooling. Since the sapphire substrate for the HgCdTe and the silicon multiplexer have slightly different

coefficients of expansion, too large a size can break bump bonds during cooling.

The second change entails moving the output amplifier to the far edge of the multiplexer and also photon shielding it so that glow from the amplifier is not detected by the HgCdTe. The original detector arrays detected glow from the output amplifier. This problem was greatly reduced by turning off the output amplifier during

integration, but the geometry solution should entirely eliminate the problem.

### 3 NEW DETECTOR FEATURES

Except for the smaller pixel size of 40  $\mu\text{m}$  and greater number of pixels, the HgCdTe photodiode array is very similar to the original 128x128 array. The smaller pixel size, however, has three potentially positive effects. First the smaller pixel size reduces its capacitance. A single photo-induced electron therefore produces a higher voltage which improves the signal-to-noise ratio per photon. In a second effect, the smaller pixel size should also have a reduced dark current. This is particularly important in spectroscopy which has a low background per pixel. Finally the smaller size of the pixel reduces the number of cosmic ray hits per pixel by a simple geometrical reduction in the cross section. Reduction of cosmic ray hits is an important factor for space experiments.

A reduction in detector size also carries the possibility of increased cross talk between pixels. Preliminary measurements on the current detectors indicates that the cross talk has an upper limit of less than 1-2 % for 60  $\mu\text{m}$  pixels and therefore is not expected to be a problem in the 40  $\mu\text{m}$  pixels.

A disadvantage of the smaller pixel size is a reduced well depth. Although borrowed from the vernacular of CCDs, well depth in the case of a photodiode is due to a different effect. Since photo induced

charge is integrated directly on the photodiode, it alters the bias across the diode. As the bias voltage changes it approaches zero bias where the diode curve is very nonlinear. There is a limit on the accuracy of the correction procedure for the nonlinearity which limits the integrations to less than 300,000 electrons for the 60  $\mu\text{m}$  pixels. This limit is expected to drop to 100,000 for the 40  $\mu\text{m}$  case. Although quite adequate for space instruments, this limit may be troublesome for wide band imaging on ground based telescopes.

### 4 GENERAL COMMENTS

The new 256x256 detectors have several advantages for the NICMOS program. The factor of 4 reduction in array number reduces the complexity of the instrument and will realize distinct savings in cost and time. In particular it eliminates the need for very accurate alignment of 4 individual arrays to form a 256x256 focal plane and eliminates the 3-6 pixel gap between the arrays required in the mosaic procedure. In future conferences such as these we will report on the results of the detector tests and results gathered with the arrays. We encourage everyone who acquires these arrays for their own use to share their experiences with the NICMOS team. We need to gather as much experience as possible to ensure that the NICMOS instrument is an extremely productive tool for the entire astronomical community.